Review of Particle Albedo

J. Eric Grove, reporting work by Allan Tylka
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This document: http://gamma.nrl.navy.mil/glast/shared/May00/Albedo_vgs.pdf
Tylka's review: http://gamma.nrl.navy.mil/glast/shared/May00/Albedo_Report.pdf

A Review of Cosmic-Ray Albedo Studies: 1949-1975

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Abstract

I review experimental results on cosmic-ray albedo from balloon and sounding rocket experiments in the 1950s, 60s, and 70s, with particular emphasis on aspects of potential relevance to backgrounds in GLAST. I also show how these early measurements have recently been confirmed by comprehensive proton-albedo measurements from the Shuttle-borne Alpha Magnetic Spectrometer (AMS).

http://gamma.nrl.navy.mil/glast/shared/May00/Albedo_Report.pdf

Definitions and History

- Two kinds of albedo are distinguished, based upon direction of motion near the top of the atmosphere (Treiman 1953):
  1. ***splash albedo***, upward moving particles emerging from the atmosphere.
  2. ***re-entrant albedo***, downward moving particles whose rigidities are below the local geomagnetic cutoff.

- "Treiman explained the close relationship between these two particle populations: the re-entrant albedo are simply splash albedo particles … [from] the conjugate mirror point in the opposite geomagnetic hemisphere."

Tylka's conclusions

1. AMS results confirm previous results, but with higher statistical precision, so they can be used for GLAST estimates.
2. Albedo spectral shape should be improved.
   - GLASTSIM uses an albedo spectral shape that is independent of latitude. This shape overestimates fluence above 200 MeV for ~1/2 the orbit.
   - [Current spectrum does indeed average to ~44 *p* m^{-2} s^{-1} sr^{-1}, as THB calculated.]
3. Zenith-angle dependence of flux is $(1 + 0.6 \times \sin\theta)$. Pat has just added this.
4. Albedo electrons must be considered.
   - Albedo electron fluence at ~100-1000 MeV is roughly an order of magnitude larger than the albedo protons in this energy range.
   - Re-entrant and splash albedo electrons are equal.
   - At ~1 GeV, albedo electron intensity ~ primary CR electron intensity.

Proton Splash Albedo

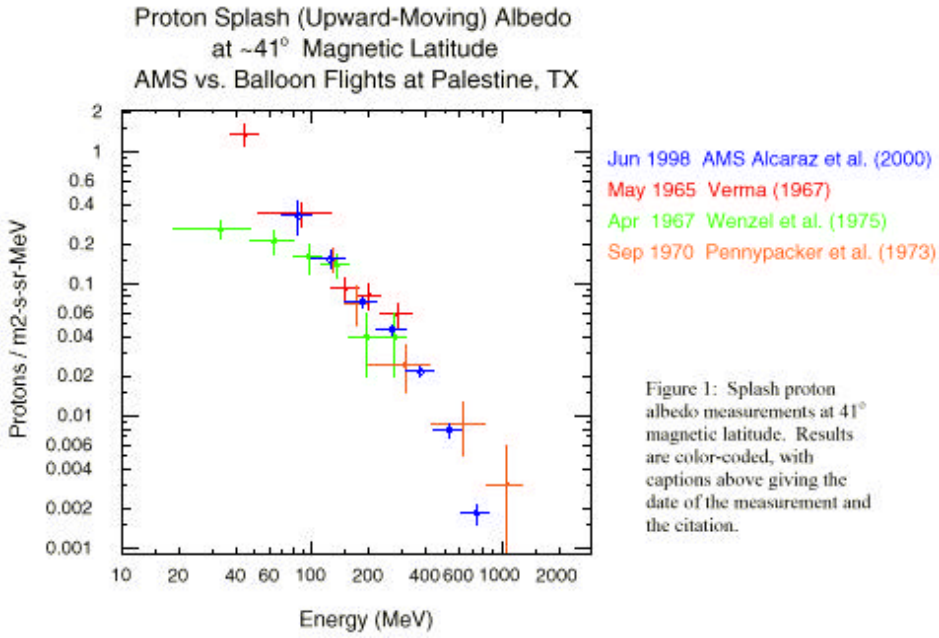


Figure 1: Splash proton albedo measurements at 41° magnetic latitude. Results are color-coded, with captions above giving the date of the measurement and the citation.

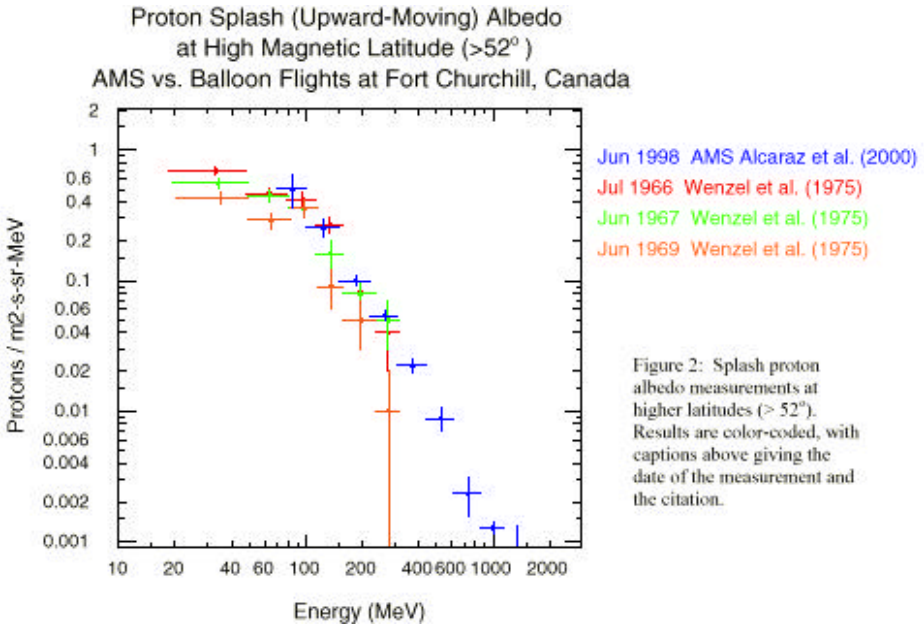


Figure 2: Splash proton albedo measurements at higher latitudes (> 52°). Results are color-coded, with captions above giving the date of the measurement and the citation.

Verma and AMS are at same phase of solar cycle, and give same spectrum and flux.

Latitude dependence of AMS data is consistent with earlier measurements at varying latitudes.

Proton Re-entrant Albedo

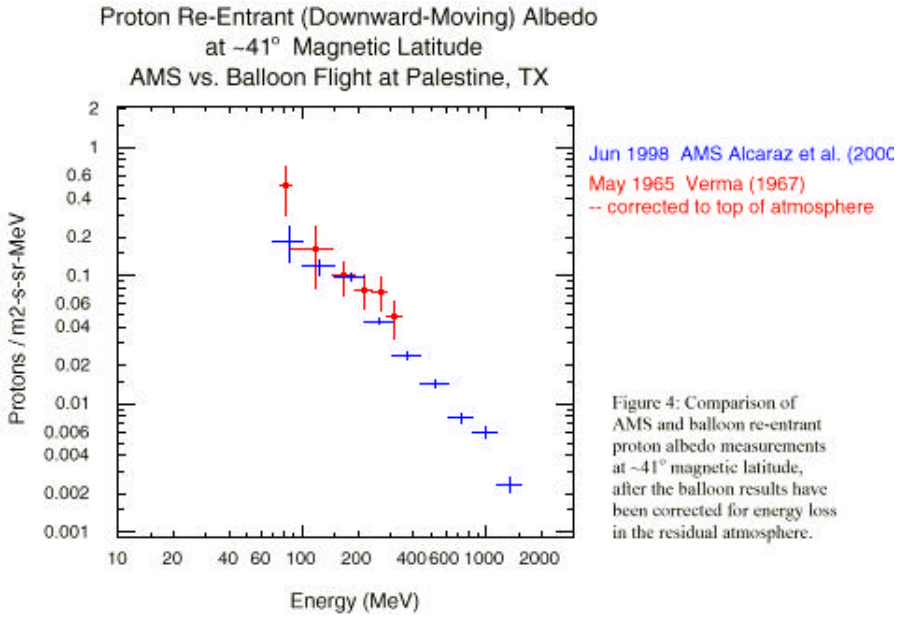


Figure 4: Comparison of AMS and balloon re-entrant proton albedo measurements at ~41° magnetic latitude, after the balloon results have been corrected for energy loss in the residual atmosphere.

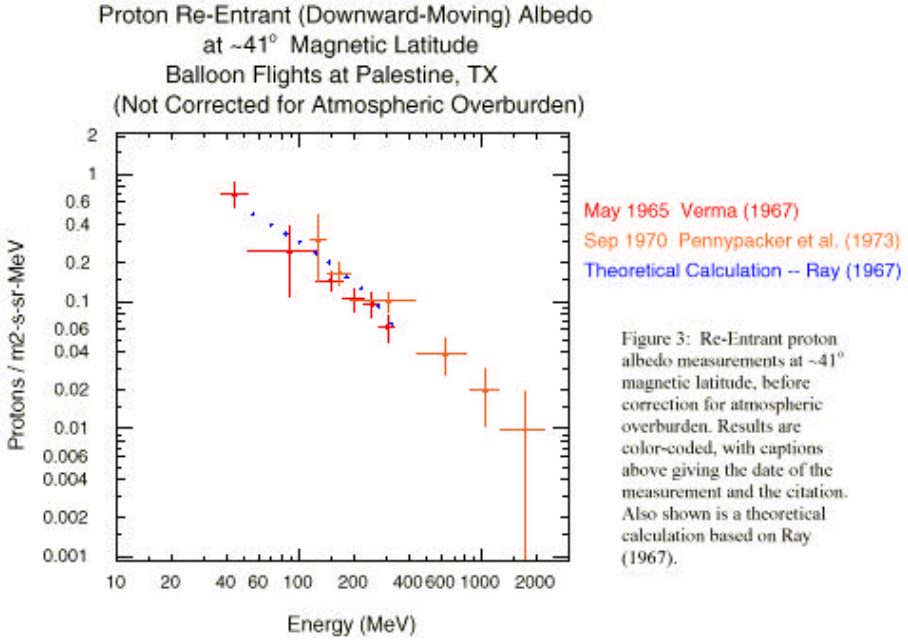


Figure 3: Re-Entrant proton albedo measurements at ~41° magnetic latitude, before correction for atmospheric overburden. Results are color-coded, with captions above giving the date of the measurement and the citation. Also shown is a theoretical calculation based on Ray (1967).

AMS confirms earlier measurement using same viewing technique.

1967 theoretical calculation *with no free normalization* describes old data. AMS should have repeated this!

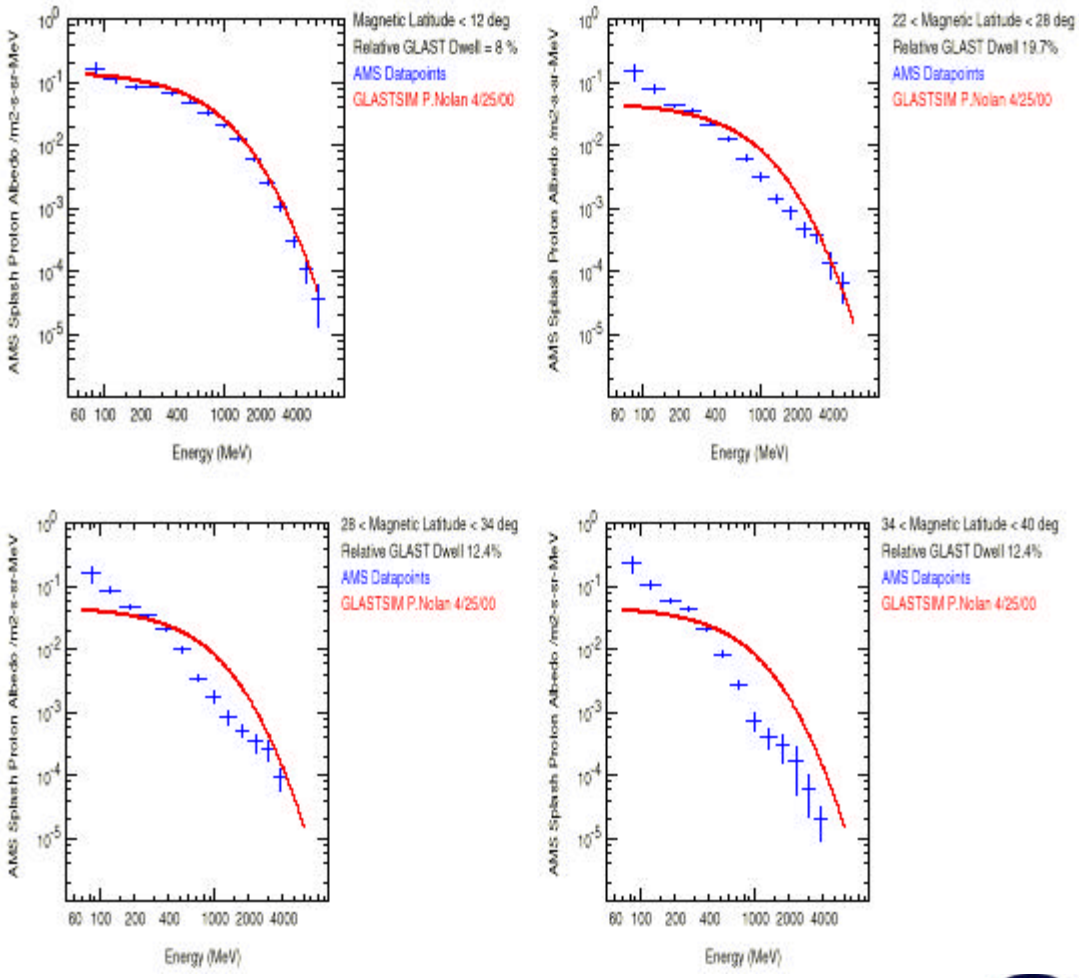
Latitude Dependence

Latitude dependence of proton albedo in GLASTSIM should be improved.

Spectral shape in GLASTSIM is independent of latitude.
AMS data in four latitude bins.

Fraction of orbit at each latitude
8% in upper left panel.
45% in other three panels.

e.g. GLASTSIM overestimates >200 MeV flux by 85% in the 28°–34° magnetic latitude bin.



Electron albedo

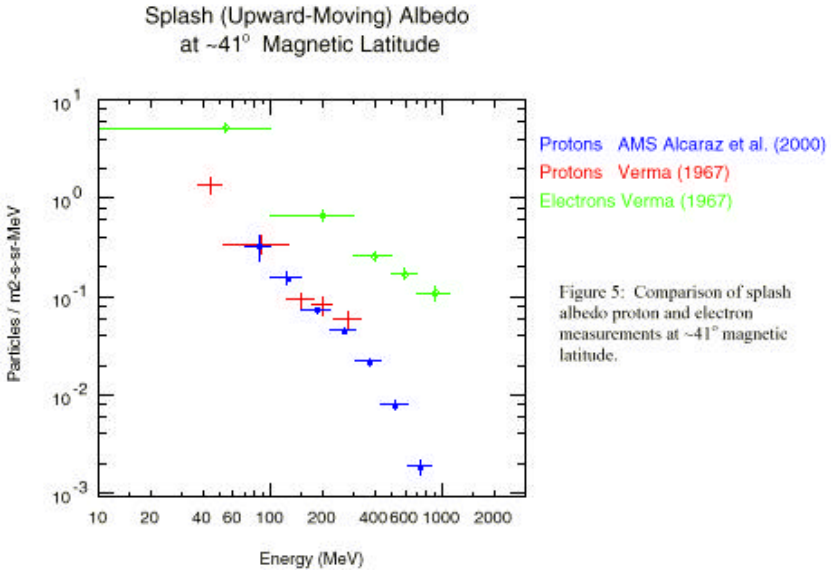


Figure 5: Comparison of splash albedo proton and electron measurements at ~41° magnetic latitude.

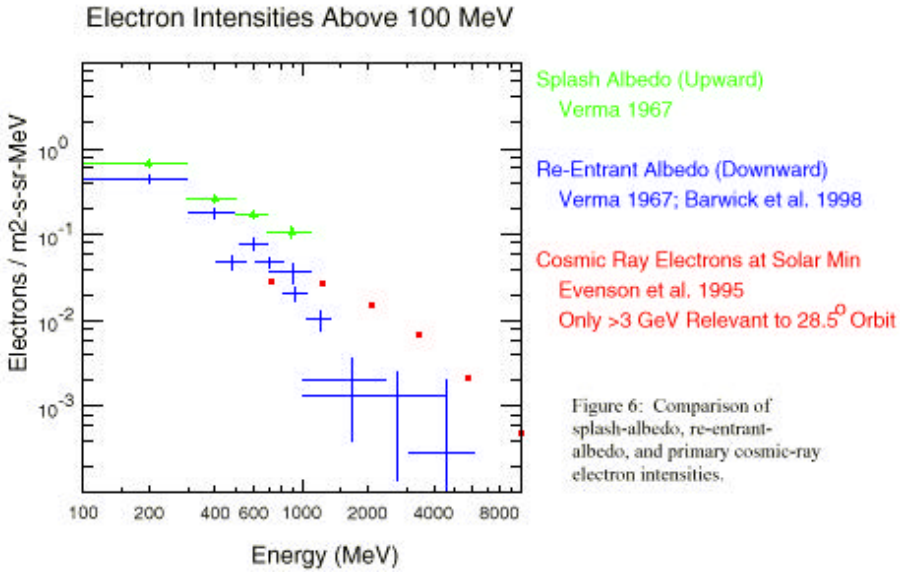


Figure 6: Comparison of splash-albedo, re-entrant-albedo, and primary cosmic-ray electron intensities.

Electron splash albedo outnumbers proton splash albedo by ~×10.

1. Re-entrant and splash albedo have comparable rates.
2. At ~1 GeV, albedo and interplanetary electrons have comparable intensity.